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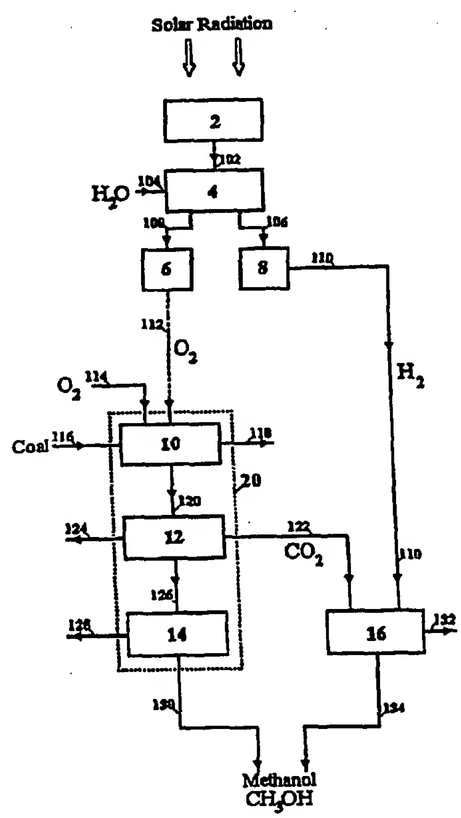
(54) Title: PRODUCTION OF METHANOL

(57) Abstract

A method and system for the production of energy-providing fuels, and particularly methanol or methanol-based derivatives, is disclosed. The system includes a methanol synthesis unit (20) that receives a supply of coal (116) and a supply of oxygen (114) from which methanol or a methanol-based fuel is synthesized and excess carbon dioxide is produced. A photovoltaic cell system (2) generates a DC power supply (102) that is provided to an electrolysis system (4) receiving a supply of water (104) to generate a further supply of oxygen (108) and a supply of hydrogen (106). The photovoltaic cell system (2) and electrolysis (4) can be located remotely from the methanol synthesis unit (20). The supply of hydrogen is transported by a pipeline (110) to a methanol production unit (16) that also receives the supply (112) of excess carbon dioxide. The methanol production unit (16) is located at the site of the methanol synthesis unit (20), and produces further methanol or a methanol-based fuel.



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PRODUCTION OF METHANOL

Field of the Invention

This invention relates to improvements in the production of energy-providing fuels. It relates particularly to methods and apparatus for the production of methanol or methanol-based derivatives as an energy-providing fuel.

Background of the Invention

Hydrocarbon substances such as methanol are useful fuel sources, in that they can be combusted to generate heat from which electricity can be derived by gas or steam turbines. Alternatively, methanol can be compressed and ignited, with the expansion energy thus liberated utilised to provide a power source for rotating engines, such as might be used in motor vehicles. Methanol also has the advantage of being readily transportable since it is a liquid at ambient temperature and pressure, and is chemically stable. The transportation modes can be pipelines or bulk carriers such as road tankers or ships.

Methanol conventionally can be produced by coal-based synthesis units, broadly comprising a coal gasification system, a gas treatment and purification system, a gas compression and methanol synthesis system, and a methanol recovery and methanol distillation system.

Coal is constituted by elemental carbon and other carbon-based compounds, together with impurities such as sulphur and nitrogen and particulates such as ash. The production of methanol from coal generates large amounts of waste carbon dioxide gas which is generally exhausted to the atmosphere. This is an undesirable occurrence since carbon dioxide is known to be a contributor to the greenhouse effect.

In contrast, the generation of electricity from coal typically takes place near coal deposits that, in most cases, are remote from the bulk of the users of electricity who are located in large cities. The transportation of electricity by long-distance high voltage transmission systems is relatively more costly than if transported as methanol.

Fossil fuels such as coal are a finite resource, and so there is an incentive to make use of that resource in the most efficient manner, and so possibly extend the time left before the resource is exhausted.

It has been proposed by the company Kansai Electric of Japan that carbon dioxide recovered from the use of fossil fuels in the generation of power in Japan could be shipped from Japan to a country such as Canada where it can be processed together with hydrogen produced by the process of the electrolysis of water to generate methanol. The electrolysis process would be based upon hydro-electric power, for example. The system proposed by Kansai Electric has two major problems, firstly that the fossil fuel-based power generation systems in Japan would need to incorporate a further system for the recovery of the carbon dioxide. Conventional power stations require significant plant investment and power consumption to implement carbon dioxide recovery. Secondly, a significant portion of the carbon in the fossil fuel thus is shipped three times between its source and the source of the electrolitically derived hydrogen. Carbon dioxide also is a difficult substance to store and transport, as it must be pressurised and placed at a low temperature for it to enter the liquid state (or as a cryogenic solid) to increase its density and thus make it efficient to transport. In comparison, methanol is relatively easy of transport.

The present invention seeks to overcome or at least ameliorate one or more of the foregoing problems.

Disclosure of the Invention

Therefore, the invention discloses a process for producing methanol or a methanol-based fuel, the method comprising the steps of:

synthesizing methanol or a methanol-based fuel from a supply of coal and a first supply of oxygen, and whereby excess carbon dioxide also is produced;

generating a DC power supply from photo-voltaic cells;

electrolysing water by said DC power supply to generate a second supply of oxygen and a supply of hydrogen; and

producing further methanol or methanol-based fuel from said hydrogen and said excess carbon dioxide.

The process can further provide for transporting said second supply of oxygen for use in said methanol synthesis step to replace or supplement said first supply of oxygen. Yet further, the process can include the step of transporting said supply of hydrogen and/or said second supply of oxygen from a location remote from the location where said synthesizing and further production steps take place.

The invention further discloses a system for the production of methanol or a methanol-based fuel, said system comprising:

a methanol synthesis unit receiving a supply of coal and a first supply of oxygen from which methanol or a methanol-based fuel is synthesized and excess carbon dioxide is produced;

a photo-voltaic cell system for the generation of a DC power supply;

an electrolysis system for the generation of a second supply of oxygen and a supply of hydrogen from water by means of said DC power supply;

means for transporting at least said supply of hydrogen from said electrolysis system to said methanol synthesis unit; and

methanol production means receiving said excess carbon dioxide and the transported supply of hydrogen for the further production of methanol or a methanol-based fuel.

Advantageously, the photo-voltaic cell system and the electrolysis system are located remote from said methanol synthesis unit and said methanol production means. The system can further comprise storage means for storing the methanol or methanol-based fuel produced by said synthesis unit and said further production unit. Preferably, said transporting means comprises a pipeline or a bulk carrier. Further preferably, the system comprises further means for transporting said second supply of oxygen from said electrolysis system to said methanol synthesis unit to replace or supplement said first supply of oxygen.

The invention further discloses methanol or methanol-based fuel produced in accordance with the above-described process or by the above-described system.

Description of the Drawing

Fig. 1 is a schematic block diagram of a methanol-producing process and apparatus in accordance with an embodiment of the invention.

Detailed Description and Best Mode of Carrying out the Invention

A known coal-based methanol synthesis unit 20 is constituted by three conventional process stages, generally represented by the reference numerals 10,12 and 14. The first stage 10 is a coal gasification system that receives a supply of coal 116 together with a supply of oxygen 114. The oxygen provided to the gasifier system 10 can be provided in bulk from a commercial supply of oxygen, or alternatively as an output product of an electrolysis process, as presently will be described. The coal gasification system 10 consists of coal grinding and feeding systems, a gasifier(s) such as those produced by Texaco, Shell Totzec, High Temperature Winkler, U-Gas or the like, ash removal systems, heat exchange system boilers and other such units normally required for coal gasification. Therefore, an impure coal-based synthesis gas is output from the gasifier system 10 via a pipeline(s) 120 to pass to the subsequent gas treatment and purification system 12. Impurities such as coal ash and water condensate are removed by an extraction system and rejected by the process output 118.

The gas treatment and purification system 12 consists of dust and particle removal systems, shift reaction and acid gas separation systems. Acidic gases consisting of hydrogen sulphide, carbon dioxide and other impurities are removed from the synthesis gas by such systems. A purified form of (excess) carbon dioxide is output by a pipeline(s) 122 for subsequent processing, as will be described. The carbon dioxide also can be stored so that a stand-by supply is available for the methanol synthesis unit 14. The hydrogen sulphide and other impurities are output by a further process output 124 to be rejected. Methanol synthesis gas consisting of hydrogen,

carbon monoxide and carbon dioxide in the correct proportions for the synthesis of methanol are output from the gas treatment and purification system 12 on a pipeline(s) 126. The synthesis gas may contain low percentages of impurities such as methane, nitrogen, argon or the like, which may be formed in the gasification stage or be present in the oxygen fed to the gasifier 10.

The synthesis gas is input to the methanol synthesis unit 14 that performs the sub-processes of gas compression and methanol synthesis, methanol recovery and distillation to produce synthesized methanol or methanol-based fuel output by the pipeline(s) 130. Gaseous impurities which are purged from the synthesis loop including methane, argon, nitrogen and the like, and further impurities removed from the impure methanol produced by synthesis such as higher alcohols and dimethyl ether and the like are rejected by a further process output 128.

For a methanol synthesis system 20 operating to produce 2000 tonne per day of methanol, approximately 2,680 tonnes per day of (excess) pure carbon dioxide also are produced. This carbon dioxide otherwise would be a waste gas. In accordance with an embodiment of the present invention, this carbon dioxide rather can be used beneficially for the further (or secondary) production of methanol or methanol-based fuel. That is, there is a known process whereby carbon dioxide and hydrogen can be processed to form methanol. Such a secondary methanol generation plant 16, preferably located at the site of the methanol synthesis system 20 also is shown in Fig. 1, and receives the supply of excess carbon dioxide on the pipeline(s) 122 from the gas treatment and purification system 12. Also provided is a supply of hydrogen on a pressurised transportation line 110. The process performed by the secondary methanol production system 16 is performed by a feed gas compression gas recirculation and synthesis unit together with product methanol distillation unit.

"Transportation" of the supply of hydrogen preferably will be by pipeline, however other forms of bulk carriage also fall within the meaning of the term, including tanker haulage by rail or road.

The resulting further methanol or methanol-based fuel is output by a pipeline(s) 134, and together with the methanol or methanol-based fuel generated by the methanol synthesis unit 20 in the pipeline(s) 130 is either stored in storage means such as tanks (not shown) for subsequent use as a fuel, else transported by pipeline (for example) for immediate use. By-products of the secondary methanol production system 16, such as higher alcohols and dimethyl ether, are removed and rejected by a yet further process output 132.

The source of hydrogen provided to the secondary methanol production system 16, in this embodiment, is transported by pipeline from a remotely located production source. The production source is constituted by an photo-voltaic cell array system 2 that converts solar radiation into a DC electrical power supply 102 provided to a known water electrolysis system 4, such as those manufactured by Lurgi of Germany or DeNora of Italy. The water electrolysis system 4 receives a supply of water 104 which is electrolysed and separately generates hydrogen gas and oxygen gas to be output upon respective gas conduits 106,108 to gas receivers or compression systems 8,6. The pressurised hydrogen gas is transported by the pipeline 110 to the secondary methanol generation system 16. The hydrogen gas generated by the electrolysis unit 4 is in the proportion 2:1 to the oxygen gas. The oxygen gas too optionally can also be transported by a pipeline 112 to the methanol synthesis plant 20, where it can be provided as the supply of oxygen gas, or by way of replacing or supplementing the bulk oxygen supply to the coal gasifier 10.

In practicality, the electrolysis unit 4 must be located proximate the cell array 2 which, in turn, is located in an area of high solar flux. Taking the example of New South Wales, Australia, the cell array 2 typically would be located in the north-west of that State, west of the Great Dividing Range. Specific locations could be Coonabarabran, Narrabri, Walgett and the like. The methanol synthesis plant would be located near the central coast of the State, that being a coal-bearing region. The hydrogen gas-transporting pipeline 110 thus would be of a length of at least 400 km. An alternative site in Australia would be at the northern end of the Bowen Basin in

North Central Queensland, where there are substantial coal-bearing deposits. The photo-voltaic cell array 2 again could be located at least 400 km away and inland in a region of high solar flux.

Similar situations arise from the point of view of the United States, where the solar collection can be performed in and around the states of Utah, Arizona and New Mexico, with the hydrogen gas (and possibly also the oxygen gas) being piped from those regions to the coal-bearing regions of the country. There are other suitable locations existing in India, South Africa and China, each of which has substantial coal deposits.

The arrangement whereby solar radiation is used as an energy source to generate at least hydrogen as a transportable fuel has great advantage over conventional photo-voltaic systems that 'transport' electricity as the 'fuel'. Particularly, it is thus not necessary to invert the DC voltage supply output by a photo-voltaic cell array to AC form, nor also to transform the inverted supply to high voltages for transmission. Photo-voltaic systems are of course dependent upon sunlight, and thus cannot generate electricity (or hydrogen as in the present embodiment) continuously. Even so, by appropriate sizing of the photo-voltaic array system 2, the amount of hydrogen generated can be in excess of the requirement of the secondary methanol generation plant 16, and can be appropriately stored (at either end of the interconnecting pipeline 110 for use on demand, and particularly during night periods. This has the further advantages of allowing continuous production of methanol, and avoiding the need for stand-by plant or costly supplies of bulk hydrogen.

For a cell array 2 sized to generate 2,300 MW over an average 8 hour period per day, approximately 366 tonnes of hydrogen and 2,930 tonnes of oxygen can be produced per day.

The hydrogen transported on the pipeline 110 typically would be compressed to 80 atmospheres and the pipeline 110 would have an internal diameter of 750 mm, which, over a 400 km distance, would result in the hydrogen being drawn off from the other end of the pipeline 110 at pressures of the order of 30 atmospheres. The oxygen

derived by electrolysis would be compressed to 60 atmospheres and the pipeline 110, having an internal diameter of 600 mm, could during 8 hour periods of rated solar radiation per day provide in excess of 80% of the total oxygen requirements of the coal gasifier 10.

For the secondary methanol generation unit 16 described, receiving the volumes of carbon dioxide and hydrogen also is noted above, approximately 1,949 tonnes per day of fuel grade methanol can be produced. This 1949 tonnes per day of methanol, following transportation, can be utilised in a 50% efficient peak shaving gas turbine/methanol dissociator generation unit(s) to provide an intermediate or peak load equivalent to 1,800 MW for 4.16 hours per nominal working weekday equivalent to 240 days per year.

In an alternative embodiment, the excess carbon dioxide and electrolytically-derived hydrogen can be combined in a secondary process stream in the methanol synthesis unit 14 in place of the secondary production unit 16.

The methanol generated by the two processes described thus is in a form for easy transportation to a customer for use as an energy source. Transportation can be by way of pipeline, ship, tanker or the like. In particular, the methanol could be shipped to other countries as a competitive fuel source. Where the end use for energy (power) occurs in winter, methanol produced in the southern hemisphere during the southern summer can be generated and transported to the northern hemisphere to meet that demand. The converse situation equally applies for the opposed seasons.

Numerous alterations and modifications, apparent to one skilled in the art, can be made without departing from the basic inventive concept. For example, the secondary methanol generation plant 16 need not be located at the site of the methanol synthesis system 20, but at some other location, possibly intermediate of the methanol synthesis system 20 and the electrolysis system 4. Alternatively, the secondary methanol generation plant 16 can be located adjacent a power generation plant, with the stored methanol being used to supplement load requirements during peak periods. The

excess carbon dioxide derived from the gas treatment and purification system 12 is readily transported by pipeline in the same manner as the electrolytic hydrogen.

CLAIMS:

1. A process for producing methanol or a methanol-based fuel, the method comprising the steps of:

synthesizing methanol or a methanol-based fuel from a supply of coal and a first supply of oxygen, and whereby excess carbon dioxide also is produced;

generating a DC power supply from photo-voltaic cells;

electrolysing water by said DC power supply to generate a second supply of oxygen and a supply of hydrogen; and

producing further methanol or methanol-based fuel from said hydrogen and said excess carbon dioxide.

2. A process as claimed in claim 1, comprising the further step of transporting said second supply of oxygen for use in said methanol synthesis step to replace or supplement said first supply of oxygen.

3. A process as claimed in claim 1, comprising the further steps of transporting said supply of hydrogen and/or said second supply of oxygen from a location remote from the location where said synthesizing and further production steps take place.

4. A process as claimed in any one of the preceding claims, comprising the further step of storing the methanol or methanol-based fuel produced by said synthesizing step and said further production step.

5. A process as claimed in any one of the preceding claims, comprising the further step of transporting the methanol or methanol-based fuel produced by said synthesizing step and said further production step to a location remote from that where the production steps take place.

6. A system for the production of methanol or a methanol-based fuel, said system comprising:

a methanol synthesis unit receiving a supply of coal and a first supply of oxygen from which methanol or a methanol-based fuel is synthesized and excess carbon dioxide is produced;

a photo-voltaic cell system for the generation of a DC power supply;

an electrolysis system for the generation of a second supply of oxygen and a supply of hydrogen from water by means of said DC power supply;

means for transporting at least said supply of hydrogen from said electrolysis system to said methanol synthesis unit; and

methanol production means and receiving said excess carbon dioxide and the transported supply of hydrogen for the further production of methanol or a methanol-based fuel.

7. A system as claimed in claim 6, wherein said photo-voltaic cell system and said electrolysis system are located remote from said methanol synthesis unit and said methanol production means.

8. A system as claimed in claim 6 or claim 7, further comprising storage means for storing the methanol or methanol-based fuel produced by said synthesis unit and said further production unit.

9. A system as claimed in any one of claims 6 to 8, further comprising means for transporting said second supply of oxygen from said electrolysis system to said methanol synthesis unit to replace or supplement said first supply of oxygen.

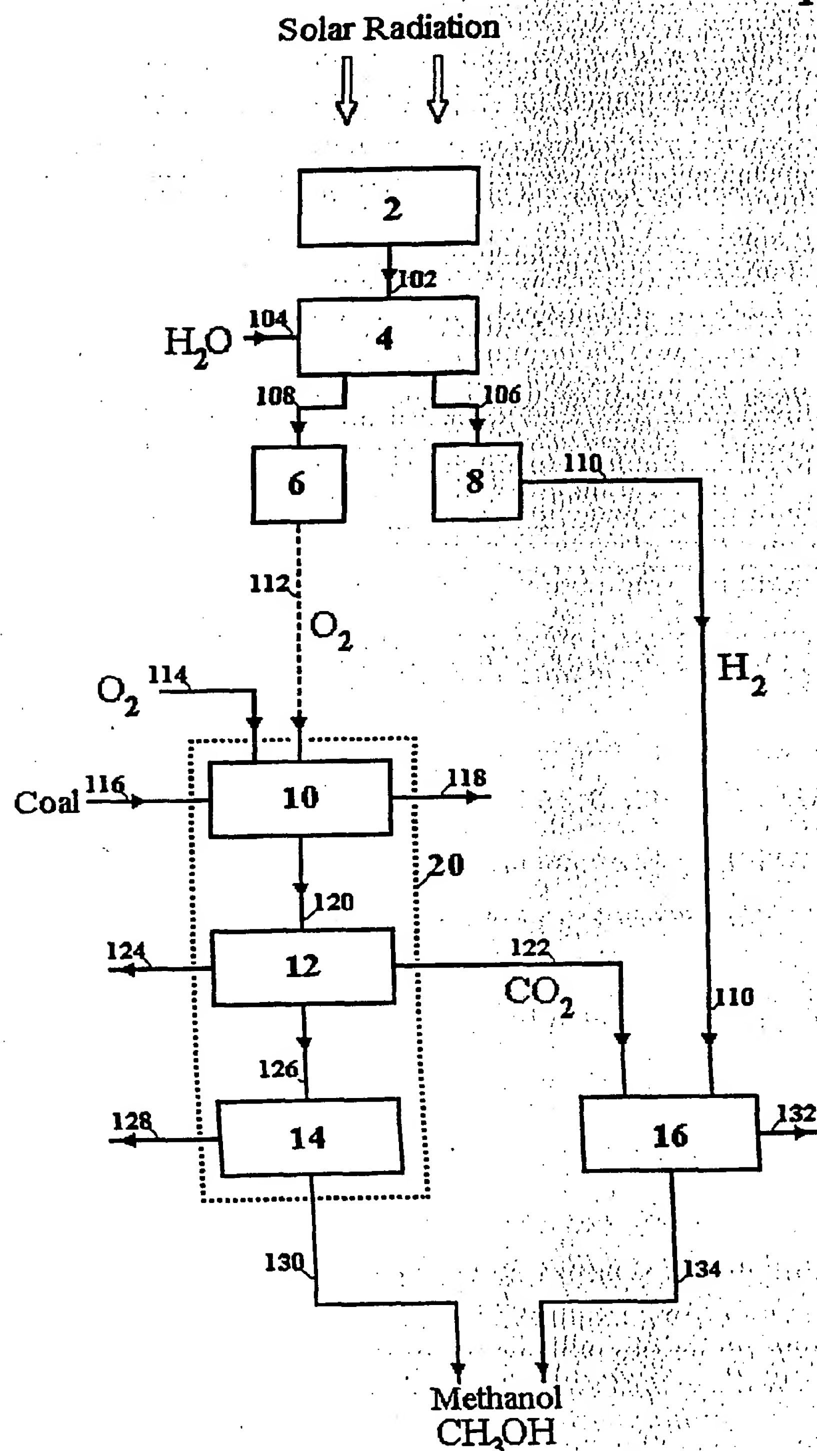
10. A system as claimed in any one of claims 6 to 9, wherein said transporting means and said further transporting means comprises two or more pipelines.

11. A system as claimed in any one of claims 6 to 9, wherein said transporting means comprises one or more bulk carriers.

12. Methanol or methanol-based fuel produced by the method of any one of claims 1 to 5.

13. Methanol or methanol-based fuel produced by the system of any one of claims 6 to 10.

Fig. 1



Solar Radiation
2
102
H_2O
104
4
108
106
6
8
110
112
O_2
H_2
O_2
114
Coal
116
10
118
20
120
124
12
122
CO_2
110
126
128
14
16
132
130
134
Methanol
CH_3OH

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 95/00284

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.[6] C07C 29/151; F24J 2/00; C10L 1/02; C25B 1/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC : C07C 29; C10L 1/02; C07C 31/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU : IPC C07C 29/151, 29/152, 29/153, 29/154, 29/156, 29/157, 29/158, 29/15 : C10L 1/02

Electronic data base consulted during the international search (name of data base, and where practicable, search terms used)
Derwent : METHANOL
Chem Abs : METHANOL AND COAL AND CARBON DIOXIDE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
P,Y	US 5342702 (MACGREGOR, N.J.) 30 August 1994 entire document	1-13
P,Y	AU 71568/94 A (ABB RESEARCH LTD) 6 April 1995 entire document	1-13
P,Y	AU 71624/94 A (ABB RESEARCH LTD) 6 April 1995 entire document	1-13

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
16 August 1995	24 AUGUST 1995

Name and mailing address of the ISA/AU	Authorized officer
AUSTRALIAN INDUSTRIAL PROPERTY ORGANISATION PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No. 06 2853929	TERRY SUMMERS Telephone No. (06) 2832291

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate of the relevant passages	Relevant to Claim No.
Y	ZAREM A.M. Ed., "INTRODUCTION TO THE UTILIZATION OF SOLAR ENERGY" (1963) McGraw-Hill, D.M. Chapin "The direct conversion of solar energy to electrical energy" pages 153-189	1-13
Y	KIRK-OTHMER, "ENCYCLOPEDIA OF CHEMICAL TECHNOLOGY", 3rd ed., volume 12, (1974), Wiley-Interscience pages 960-965	1-13
Y	KIRK-OTHMER, "ENCYCLOPEDIA OF CHEMICAL TECHNOLOGY", 3rd ed., volume 15, (1978), Wiley-Interscience pages 400-407	1-13
	J. K. Paul, Ed., "METHANOL TECHNOLOGY AND APPLICATION IN MOTOR FUELS" 1978, Noyes Data Corporation (USA)	
Y	pages 87-96	1-13
Y	pages 107-165	1-13

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member	
US	5342702	CA	940706

END OF ANNEX